THE IMPACT OF STREAM MODIFICATION ON THE DISTRIBUTION OF RIVERINE TURTLES IN IOWA

A Thesis Presented to

The College of Arts and Sciences

Drake University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

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by

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May 1993

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An abstract of a Thesis by

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Comparisons were made of turtle populations in Red Rock Reservoir, the Des Moines River, and other rivers of the Mississippi River drainage system in Iowa. In addition, comparisons were made of turtle populations in rivers of the Missouri River drainage system in Iowa. Of the inland rivers of the Mississippi drainage examined in this study, the Des Moines River has undergone the greatest amount of modification. Number of turtle species ranged from five in the Des Moines River to 11 in the Mississippi River, but only three species were found in Red Rock Reservoir. In the Missouri drainage, number of turtle species ranged from three in both the Little Sioux and Nishnabotna rivers to five in the Missouri River. Stream modification appears to lower the diversity of riverine turtles by eliminating intolerant species. The mechanism for this elimination is probably a reduction in habitat diversity, creating a more uniform and simplified environment. False map (*Graptemys pseudogeographica*), smooth soft-shell (*Trionyx muticus*), and Blanding's turtles (*Emydoidea blandingi*) appear to be most affected by modification. Turtle diversity was lower in Red Rock Reservoir than in the Des Moines River, possibly due to the great fluctuation in the water level of the reservoir.

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INTRODUCTION

Homesteaders in Iowa discovered a land of flat to rolling prairie crisscrossed with forested river valleys. Scattered throughout were thousands of potholes, marshes, and old river oxbows. The rich prairie soil was ideal for crop production, especially in river bottom areas. Early farming efforts were often hampered by frequent flooding and slow drainage of floodwaters from prime agricultural land. To ensure maximum yields, more rapid and effective drainage of cropland was needed. Drainage and flood control resulting from channelization of rivers and streams allowed conversion of some poorly drained bottomland to cropland (Best et al., 1978). Landowners began installing drainage tile and reclaiming marshes and oxbows for agricultural use. Later, as more and more towns were built along rivers, increased flood control and navigation became important. Recently, stream modifications in Iowa have generally been short realignments for bridge work and bypassing of meanders with new channels (Best et al., 1978). Over the last several decades, numerous flood control impoundments (reservoirs) have been constructed on rivers. These reservoirs hold back floodwaters so that they may be released slowly to reduce flood damage downstream.

This history of stream alteration has resulted in a reduction of stream miles and loss of their associated riparian habitats. Bulkley et al. (1976) estimates stream loss for the Missouri River drainage in Iowa at 1,240 miles and for the Mississippi River drainage 1,775 miles, resulting in anywhere from 1,000 to 3,000 miles of stream lost in the state. Associated with loss of stream miles is a change in land use practices along channelized segments. Best et al. (1978) report that herbaceous cover decreased significantly and cropland increased significantly at channelized segments, while vegetation cover did not change significantly at unchannelized sites. Best et al conclude that stream alteration does affect land use over time. Frequently, in order to maximize yields, a landowner plants crops adjacent to the edge of a stream, subsequently eliminating the riparian habitat in that area.

Stream modification (channelization) activities include clearing and snagging, riprapping, widening, deepening, realignment, and lining (Simpson et al., 1982). The objective of channelization, in many areas, is the rapid removal of standing water, which is accomplished by lowering the water table adjacent to the channel (Vandre, 1975). Lowering of the water table may also result in the dewatering of wetland areas often associated with streams. Clearing and snagging (removal of bank vegetation and large woody debris from the channel) may be used for reducing the stage and duration of high frequency flooding (Smith and Shields, 1990), and for improving navigability. In addition, stream banks may be raised by constructing levees and dikes (which are often riprapped for stabilization) to confine floodwaters to the river channel, and to prevent the river from encroaching on cropland.

Altering streams impacts aquatic and riparian communities in various ways. Simpson et al. (1982) list some of the major consequences of channelization as: loss of specific substrate, removal of snags and root masses, loss of instream and streamside vegetation, disruption of run-riffle-pool sequence, increased gradient and velocity, dewatering of adjacent lands, and loss of overall stream length. Possibly the most important impact on wildlife is the resultant loss of habitat diversity after channelization (Bulkley et al., 1976; Paragamian, 1987; Simpson et al., 1982; Smith and Shields, 1990).

The biological impact of channelization was first identified by Langlois in 1941 as a shift in the species composition of fishes (Simpson et al., 1982). Since then, extensive work has been done on the impact of stream modification on fishes. Simpson et al. (1982) report that channelization affects individual fish by affecting niches, food, reproduction, and behavior. At the population level, density and distribution are affected, and at the community level all interactions are affected. In Iowa, elimination of 11 species of fish was reported from the Upper Des Moines River between 1892 and 1951 when stream modification activity was most common (Bulkley et al., 1976). Welker (1967) found channel catfish (*Ictalurus punctatus*) were more abundant in unchannelized sections of the Little Sioux River than they were in channelized sections. Paragamian (1987) found that channelized sites contained fewer fish and substantially lower standing stocks of fish than natural reaches. In addition, Paragamian found that the Index of Biotic Integrity average was higher at natural stream reaches than channelized sites.

The effects of channelization on other vertebrate species are less well known. Geier and Best (1980) state that habitat alterations, such as channel realignment, can affect small mammal populations and alter community composition. They found that small mammal species diversity was higher in channelized habitats, possibly due to the presence of grassland vegetation. Vandre (1975) reported increased predation on waterfowl nests in channelized areas due to loss of cover. Vandre also found lower species diversity for waterfowl, nongame birds, and mammals in channelized areas. Benson and Weithman (1980) reported that channelization and drainage of wetlands nearly wiped out populations of amphibians and reptiles in Wisconsin. Simpson et al. (1982) report that habitat loss through loss of meanders, pools, overhangs, and bank vegetation reduces populations of herpetofauna in channelized areas.

The effects of channelization on turtle species are not well known. Maki et al. (1980) suggest that berm, depending on slope, may affect the mobility of turtles when they try to find nest sites away from water. In Missouri, populations of *Trionyx* and *Graptemys* are thought to be declining in some areas due to channelization (Johnson, 1987). In Germany, Thienemann (1950) reports the elimination of the common European pond turtle (*Emys orbicularis*) from the Rhine River after regulation.

The effects of reservoir construction on river organisms have been studied by several researchers. These studies provide conflicting evidence concerning the impact of building reservoirs on rivers. Working with phytoplankton in Brazil, Chellappa (1990) concluded that species diversity was less in reservoirs than in the associated rivers. Neck (1989) working with fingernail clams also found lower diversity in reservoirs. Both workers found increased densities of the species that did exist in the reservoir. Working with fish, Casado et al. (1989) compared rivers immediately upstream from reservoirs with those downstream and found increased biomass upstream. Marzolf (1984), in a discussion of great plains reservoirs, states that fish diversity will be highest at the reservoir/river interface and decrease as one moves toward the dam, as long as no new species have been introduced into the reservoir. Gilbert (1991) concluded that constructing reservoirs on rivers improves biodiversity, and reports a 50% increase in the number of bird species sighted at Lake Red Rock over the past two decades. No study to date has examined the impact of construction of a reservoir on riverine turtle populations.

The original objective of this study was to compare the diversity of turtles in the Des Moines River with the turtle diversity of a flood control impoundment, Red Rock Reservoir. During the course of the study, it was discovered that the Des Moines River had a lower turtle diversity than was initially expected, and an investigation into possible reasons for this was initiated. This study therefore examines the impact of stream modification, whether by channelization or reservoir construction, on turtle abundance and diversity. It tests the null hypothesis that riverine turtle populations are not influenced by stream modification practices, either channelization or construction of artificial reservoirs.

MATERIALS, METHODS, AND DESCRIPTION OF AREAS

This study was conducted from September 1991 through November 1992, with the recent turtle trapping done from May 1992 through August 1992. Research collections from Drake University, University of Michigan, Dr. Reeve Bailey's personal records, Iowa State University, the U.S. National Museum, Coe college, the Field Museum of Natural History, University of Nebraska, University of Utah, Buena Vista College, and

Luther College were examined for locality records of Iowa turtles. The collection locations of all turtles known to have been taken from Iowa were used to construct Iowa distribution maps. Species included were painted (*Chrysemys picta*), snapping (*Chelydra serpentina*), spiny soft-shell (*Trionyx spiniferus*), smooth soft-shell (*Trionyx muticus*), false map (*Graptemys pseudogeographica*), map (*Graptemys geographica*), red-eared (*Trachemys scripta*), Blanding's (*Emydoidea blandingi*), stinkpot (*Sternotherus odoratus*), Illinois mud (*Kinosternon flavescens spooneri*), and alligator snapping turtles (*Macroclemmys temmincki*). Chelonian community similarity and diversity were calculated and compared for the major Iowa rivers in the Mississippi and Missouri River drainage systems. The results were tabulated and where appropriate statistical tests of significance were performed.

The comparisons of turtle distributions among Iowa's rivers required the use of verifiable locality records obtained prior to the present study. The collection dates of these records are shown in Table 1. A large percentage (88.7%) of these specimens were collected after critical river modification took place. By 1930, extensive modification of the Des Moines River was complete (U.S. Government, 1931; Dr. W. E. Akin, Drake University, Pers. Comm.).

The greatest number of records were obtained from the Drake University Research Collection. These records reflect extensive surveying done by Drake University biologists over the past twenty years. In all instances, with the exception of most of Dr. Reeve Bailey's personal records, the localities used were supported by a preserved specimen. A few specimens obtained in the late 1800's or early 1900's have shipping points rather than actual collection sites as their localities. These, and specimens clearly out of their normal habitat (i.e. likely released captives), are considered questionable specimens and are represented on maps with a "?" and are not included in our analysis.

Table 1. Collection dates for turtle records from Iowa used in this study.

Institution	# of specimens	% of total	Collection dates
Drake University	676	57.00	1969 - Present (100%)
Univ. of Michigan	173	14.60	1907 - 1956 (100%)
Dr. Reeve Bailey's Personal Records	163	13.70	1938 - 1942 (95%)
Iowa State University	81	6.80	1923 - 1954 (100%)
U.S. National Museum	63	5.30	1878 - 1916 (95%)
Coe College	11	0.92	1952 - 1951 (100%)
Field Museum	10	0.84	1941 - 1957 (90%)
Univ. of Nebraska	6	0.51	-------------
Univ. of Utah	2	0.17	1963 (100%)
Luther College	1	0.08	1972 (100%)
Buena Vista College	1	0.08	1963 (100%)
Totals	1187	100	88.7% > 1930

Excludes massive collections made at a single locality (i.e. > 70 *K. flavescens spooneri* at Big Sand Mound).

Mississippi River drainage

Mississippi River. The Mississippi River, which forms the eastern border of Iowa, is the third longest river in the world. The river and its tributaries drain nearly one-third of the land surface of the United States (Harlan, Speaker, and Mayhew, 1987), and nearly two thirds of Iowa. Its course meanders through a series of sloughs and channels across a two- to six-mile wide valley, and becomes wider as it moves south. Originally the river was a network of sloughs, channels, bars, and rapids, with a main channel that was often blocked with rocks and snags. In 1824, Congress approved removal of the snags and clearing of the channel to improve navigation. Today eleven permanent dams affect the river bordering Iowa (Harlan, Speaker, and Mayhew, 1987). Even with the extensive modifications, many sloughs and backwaters may still be found. Major Iowa tributaries include the Cedar, Iowa, and Des Moines rivers.

Cedar River. The Cedar River enters northern Iowa from Minnesota and runs for nearly 300 miles before joining the Iowa River in the southeast part of the state. It is a slow moving river that meanders through limestone valleys and hardwood forests. Many backwater areas and oxbows are found along its' course. There are eleven low head dams and four on-stream dams that affect the northern two thirds of the river (Harlan, Speaker, and Mayhew, 1987).

Iowa River. The Iowa River headwaters in northcentral Iowa and runs for slightly over 320 miles before emptying into the Mississippi. It is joined by the Cedar River in southeast Iowa making it the states second largest interior stream. The upper sections of the river have been channelized to promote drainage, and it has been impounded in twelve locations, with the largest being Coralville Reservoir in Johnson County (Harlan, Speaker, and Mayhew, 1987). The lower portion of the river (after its confluence with the Cedar) is a wide river with numerous sloughs, oxbows, and small islands.

Des Moines River. The Des Moines River is the state's largest interior stream, entering northern Iowa from Minnesota and traveling southeast 535 miles before joining the Mississippi River near Keokuk. The northern one half has been extensively channelized (Bulkley et al., 1976). The lower half consists of three natural divisions: 1) the lower division, a wide floodplain with a narrow channel; 2) the middle division, unique for its gorge-like valley, with banks from 12 to 20 feet high carved by meltwater from the Wisconsinan glacier; and 3) the upper division, running through an alluvial valley with steep bluffs and sharp bends (Harlan, Speaker, and Mayhew, 1987). Two flood control impoundments, Saylorville near Polk City and Red Rock near Pella, have been constructed on the river.

Flooding had been a problem in the Des Moines River valley since the arrival of the first settlers. Levees and dikes were constructed to help confine floodwaters to the channel. By 1931 the last 10 miles of its course had been leveed, and most of its major tributaries channelized (U.S. Government, 1931). In the early part of this century dredging was initiated to keep the channel deep and clear (U. S. Army Engineers, 1975). Dredging, which increases channel capacity and velocity of flow, allowed the river to carry more water, and move it more rapidly downstream. While there is very little evidence of extensive channel realignment projects along the lower Des Moines, the river banks in many areas have been riprapped to provide stabilization. In the 1960's, Red Rock Reservoir was constructed near Pella as a flood control impoundment. It is estimated that the project has prevented nearly $100 million in flood damages since its construction. Harlan et al. (1987) refer to numerous old oxbow lakes along the lower Des Moines River. Attempts to locate these oxbows during the field season of 1992 were unsuccessful. Nearly all old oxbows and marshes along the river have been drained for agriculture. Of the inland rivers of the Mississippi River drainage that were examined in this study, the Des Moines has been the most modified (Dr. W. E. Akin, Drake University, Pers. Comm.).

Missouri River drainage

Missouri River. The Missouri River, which forms two thirds of the western border of Iowa, is one of the most altered rivers in the world. The river drains roughly the western third of the state before it flows into Missouri. Its original course was meandering and lined with backwaters and oxbow lakes. The channel was turbid and full of snags. Today, the Missouri has been converted into a narrow, smooth channel with gentle bends, resulting in a loss of nearly 35,000 acres of channel area in Iowa (Harlan, Speaker, and Mayhew, 1987). A few large oxbow lakes remain, most notably DeSoto Bend in southwest Harrison County.

Little Sioux River. The Little Sioux River is the largest Iowa stream flowing into the Missouri River. Near the headwaters the channel is shallow and meandering, farther downstream it widens and deepens. The lower portion of the river has been channelized and flows into the Missouri through the Harrison-Monona drainage ditch (Harlan, Speaker, and Mayhew, 1987). Several on-stream impoundments and dams are found along the river.

Nishnabotna River. The east and west Nishnabotna both headwater in west central Iowa and flow southwest until they join near the town of Riverton. Almost the entire course of both channels have been straightened and deepened, and vertical banks up to 20 feet high are common (Harlan, Speaker, and Mayhew, 1987). In most places, the stream resembles a ditch more than a river.

Red Rock Reservoir

Study area. Red Rock Dam (Figure 1) is located on the Des Moines River in Marion County, Iowa approximately 40 miles southeast of the city of Des Moines. Work on the dam began in 1960 and was completed in 1969. High water that spring allowed the lake to fill in only four days. The normal pool level of the lake has changed dramatically over the years. In 1972 the normal pool covered 8,950 acres (U.S. Army Engineers,

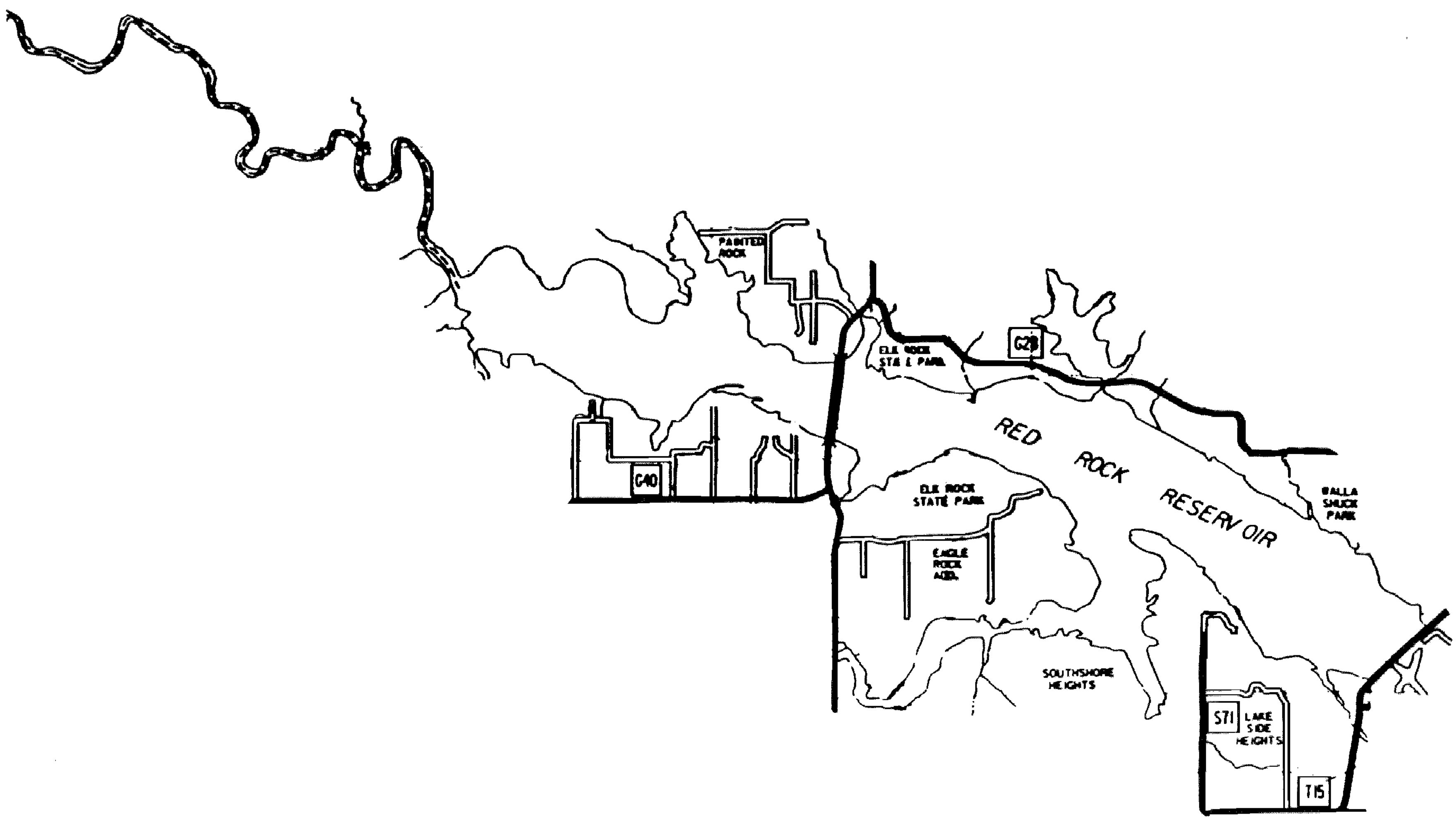

Figure 1. Red Rock Reservoir.

1975), in 1991 13,000 acres (U.S. Army Corps of Engineers, 1991), and as of April 1992 19,000 acres (U.S. Army Corps of Engineers, Pers. Comm.). During periods of flooding the pool area may expand to cover 65,000 acres. The lake is surrounded by approximately 35,000 acres of government owned land, and numerous small streams form the channels of most bays. These streams often carry large amounts of silt into the lake. Many bays within the lake are large with little shallow water. Most of the bays are accessible by car, and as a result receive high human use. Depending on rainfall, the level of the lake fluctuates greatly.

Trapping methods. Binocular surveys and scouting for suitable trapping sites began on 13 May 1992. All major bays of the lake along with backup areas were surveyed in an attempt to locate sites with abundant basking logs or sand banks, moderately shallow water, and low human use (to minimize trap loss). Possible trapping sites were recorded for future use.

Trapping began on 18 May 1992 and ended on 17 August 1992. The traps used were new, modified fyke nets as described by Legler (1960). Traps were baited with fish that had been bought, or fresh trash fish caught in the traps. The bait was placed in screened baitholders and suspended from the top of the trap. Traps were checked and rebaited daily between 0730 h and 1200 h. Whenever possible, traps were placed so that the tops were submerged no more than a few centimeters, allowing the turtles to reach the surface for air. A small number of traps were set deep (5 - 7 feet) in an effort to catch deep-feeding turtles. All habitat types within each bay were sampled. Turtles captured were released, with the exception of one specimen of each species, or more if more than one died, which were kept as voucher specimens from each major sampling area.

Additional trapping was done at three locations in the Des Moines River south of Red Rock Reservoir. These sites were: 1) An oxbow immediately below the spillway of Red Rock; 2) An oxbow and an estuary on the Marion - Mahaska County line; and, 3) A sand pit adjacent to the river in Farmington, Iowa. Trapping methods were the same as above.

Preservation of specimens. Four specimens of *C. picta*, two of *C. serpentina*, and three of *T. spiniferus* were retained from Red Rock Reservoir and its backup areas. One specimen of *C. picta*, one *C. serpentina*, three *T. spiniferus*, and four *T. scripta* were kept from the three Des Moines River locations south of Red Rock. The shell and soft parts method was used for preservation (Christiansen and Dunham, 1972). Shell, skin, and reproductive organs were all tagged separately. After fixing in 13% formalin, the skin was transferred to 70% ethanol and the gonads to 10% formalin. The shells and cleaned skeletons were stored dry, with the exception of *T. spiniferus* shells which were stored in 10% formalin. All specimens were placed in the Drake University research collection.

RESULTS

Turtle distribution in Iowa

Distributions of Iowa's riverine turtles are shown in figures 2 - 12. Solid dots represent all known localities where specimens have been collected. Question marks indicate questionable specimens.

***Chrysemys picta* and *Chelydra serpentina*.** Both painted and snapping turtles are common and abundant in rivers, streams, lakes, ponds, and marshes throughout the state (Figures 2 and 3). Construction of farm ponds may have increased their numbers in some areas. Conversations with state conservation officers suggest that populations of *C. serpentina* may be declining in some heavily trapped areas due to overharvesting for meat.

***Trionyx spiniferus*.** Spiny softshell turtles are a fairly common species found throughout the state, with the exception of the northwest corner (Figure 4). These turtles are found in rivers, streams, and adjacent permanent and temporary ponds. Trapping

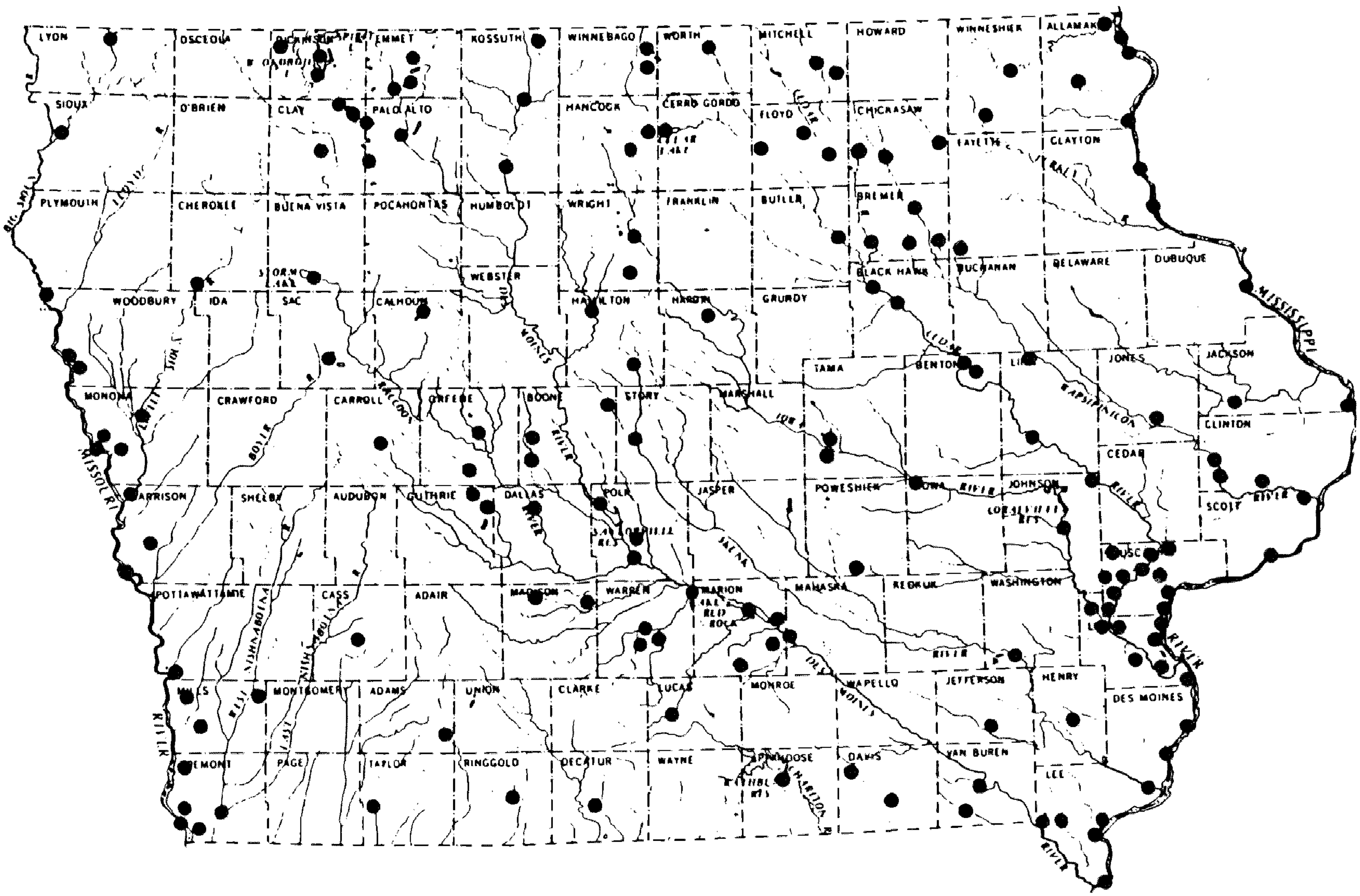

Figure 2. Collection locations for the western painted turtle (*Chrysemys picta belli*).

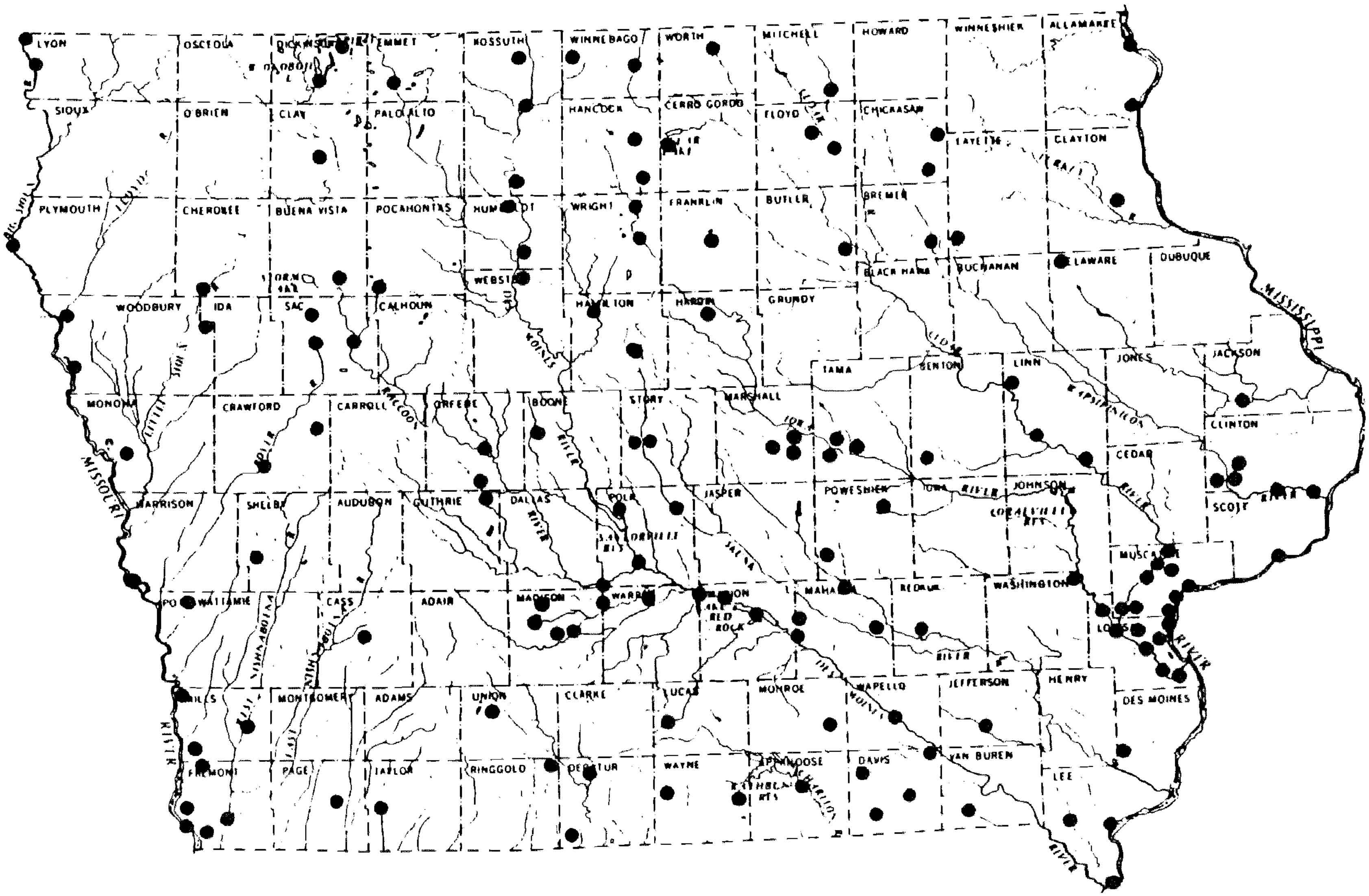

Figure 3. Collection locations for the common snapping turtle (*Chelydra serpentina*).

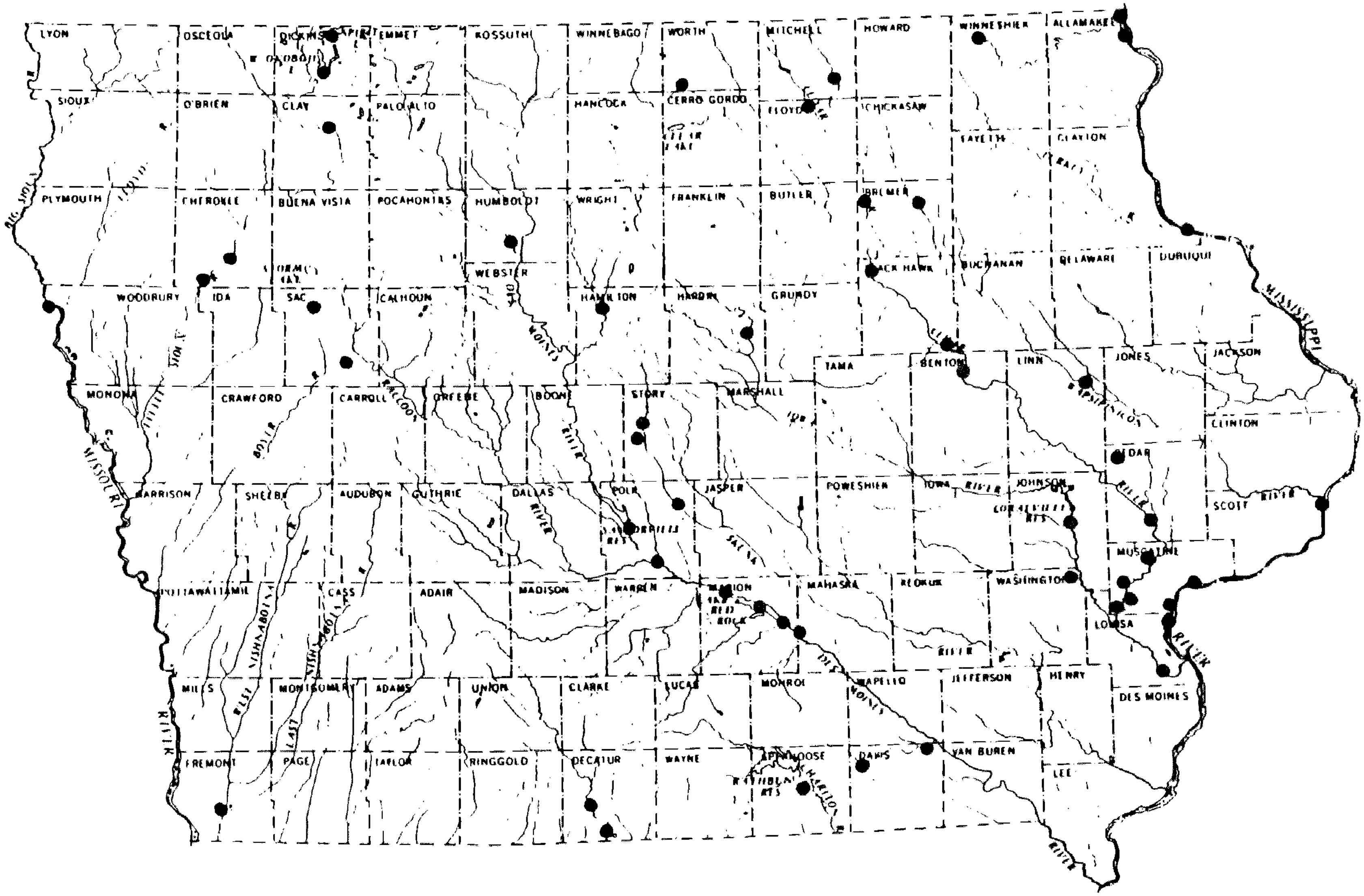

Figure 4. Collection locations for the eastern spiny soft-shell (*Trionyx spiniferus*).

evidence indicates that *T. spiniferus* is abundant in the eastern half of the state, and only moderately abundant in the west.

Trionyx muticus. Smooth softshell turtles prefer rivers to ponds and are generally found in the large downstream portions of rivers in Iowa (Williams and Christiansen, 1981). They are absent from the northern third of the state except for the Mississippi and Missouri rivers (Figure 5). Significant is the lack of any collected specimens of *T. muticus* in the Des Moines River, including Red Rock Reservoir, below the city of Des Moines. Trapping in the river during the field season of 1992 (> 50 trap nights) yielded *C. picta, C. serpentina, T. scripta,* and *T. spiniferus*, but failed to produce any *T. muticus*. Both old and recent records for *T. muticus* are present for the Des Moines River north of Red Rock Reservoir.

Graptemys pseudogeographica. The Iowa distribution of false map turtles is particularly interesting when the general range of the species is considered. The turtle is found in both the Mississippi and Missouri rivers, and to the north and south of Iowa. But it is conspicuously missing from the Des Moines River which runs through the middle of the state (Figure 6). In addition, it has not been found in any of the western rivers that feed into the Missouri. Two large eastern rivers (Cedar and Iowa) both support healthy populations of *G. pseudogeographica,* with the Cedar River population reaching into Blackhawk County, and the Iowa River population into Iowa County.

Graptemys geographica. Map turtles are confined to the large rivers of the Mississippi River drainage (Figure 7). A few specimens have been collected in the lower reaches of the Cedar, and in the Iowa as far north as Iowa City. A 1941 Iowa State University record shows a specimen taken from the Cedar River in Floyd County ("vicinity of Charles City"). Our studies suggest it is doubtful that this specimen came from a population of *G. geographica* inhabiting the Cedar River in that area. It is likely that it was

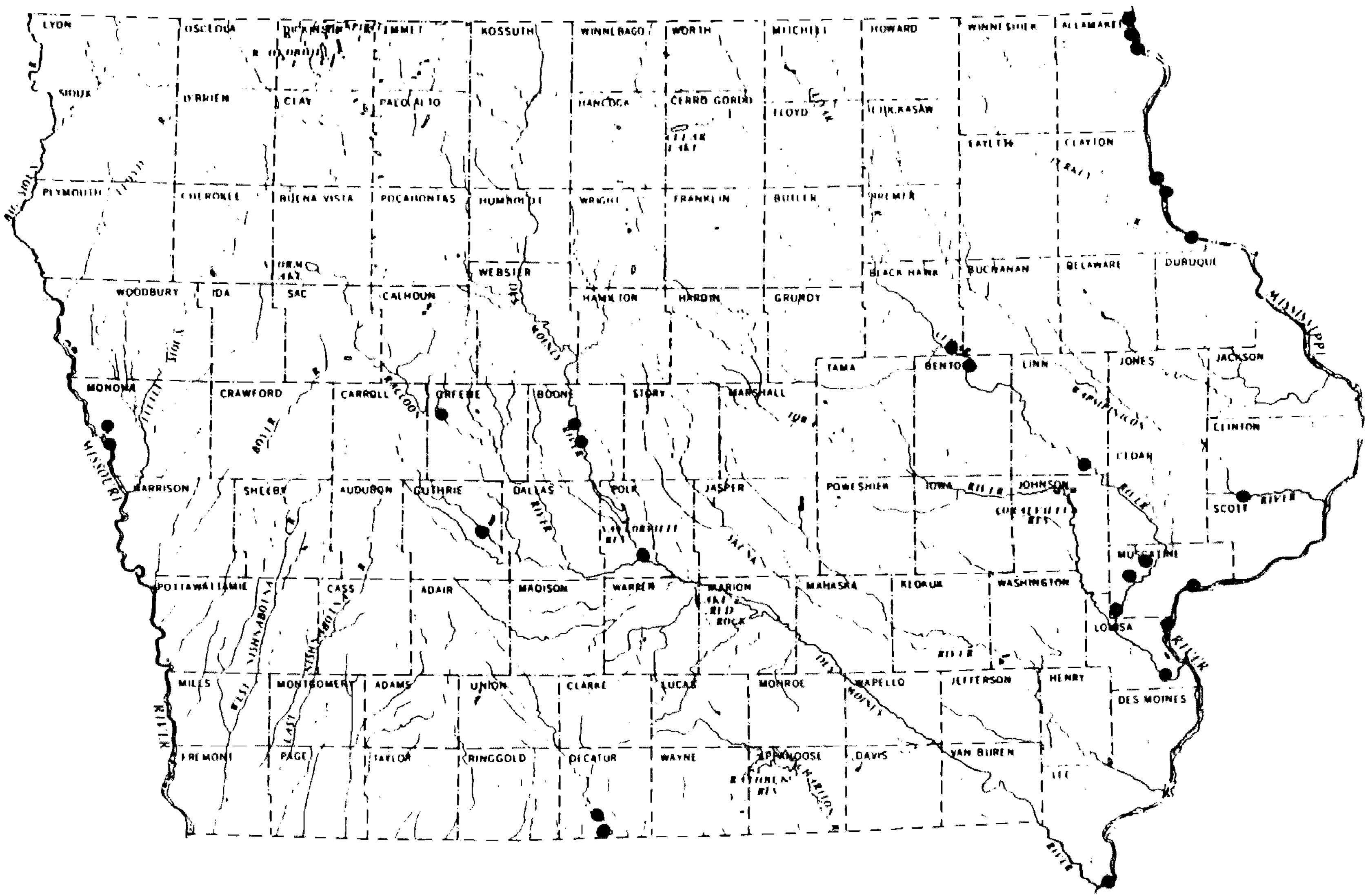

Figure 5. Collection locations for the smooth soft-shell (*Trionyx muticus*).

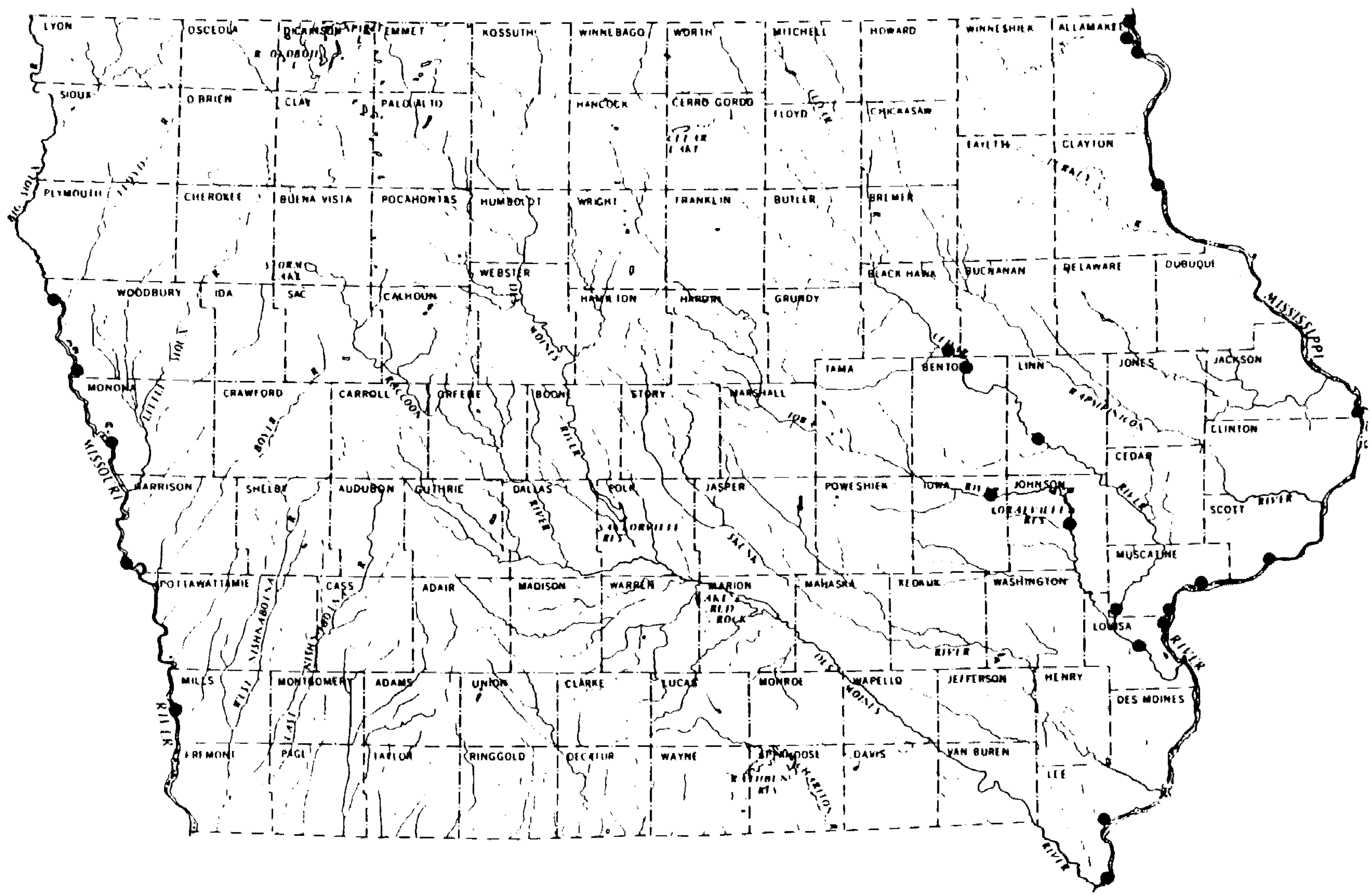

Figure 6. Collection locations for the false map turtle (*Graptemys pseudogeographica*).

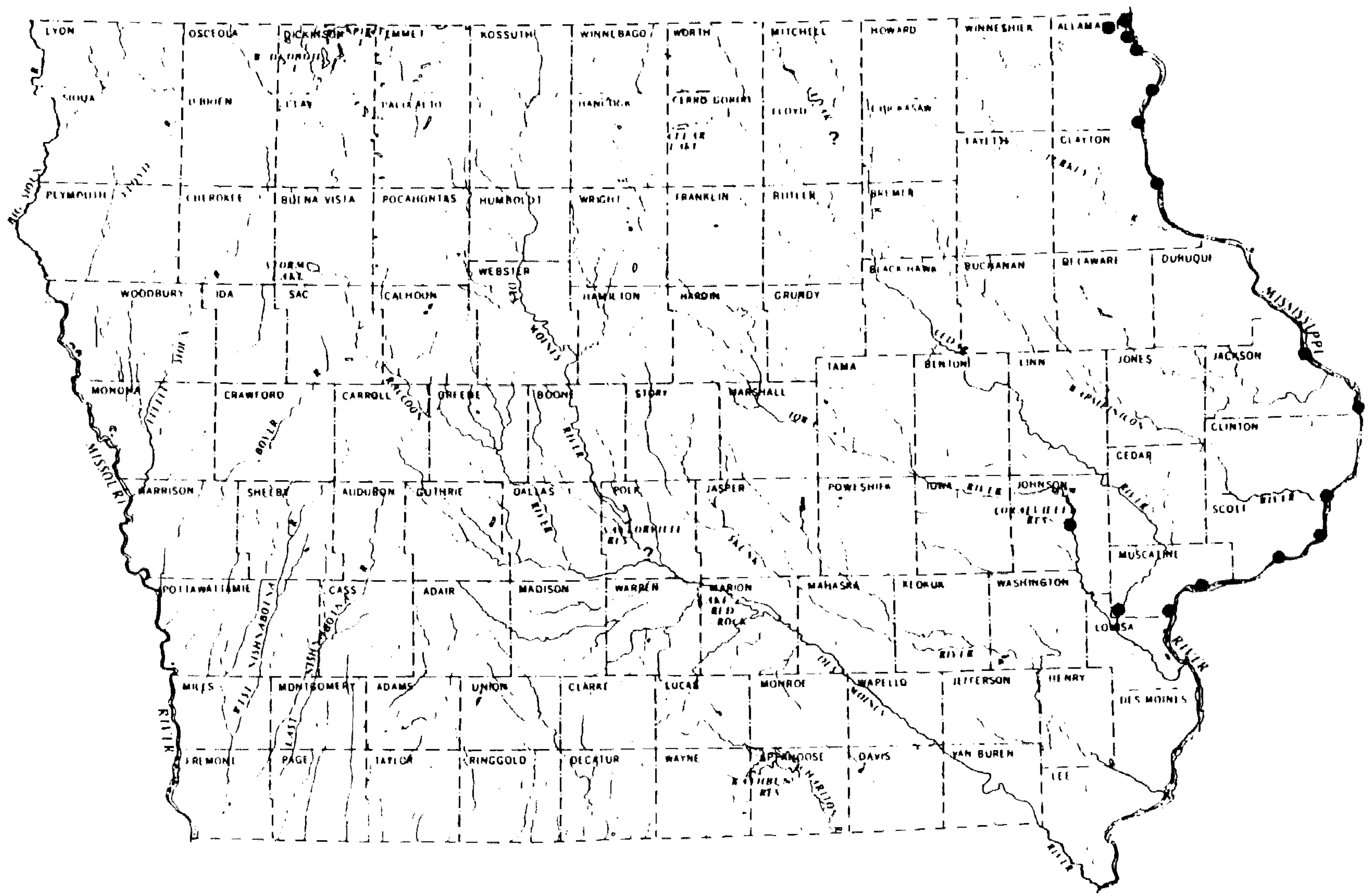

Figure 7. Collection locations for the map turtle (*Graptemys geographica*).

a released captive. To date, no specimens have been taken from the lower Wapsipinicon, Skunk, or Des Moines rivers.

Trachemys scripta. Red-eared turtles are limited to large rivers in southeast Iowa (Figure 8). Several specimens have been taken from the lower Mississippi, Cedar, and Iowa rivers. To date, *T. scripta* has only been found in one location along the Des Moines River. This population was discovered during the field season of 1992, and while it is large and reproducing, somewhat atypical shell markings suggest that the population may be introduced. Consistent slightly atypical markings could be expected from an inbred population as well. Three questionable *T. scripta* records exist from the state. One from a pond in the city of Des Moines; one from the Cedar River in Johnson County; and, one from a trout stream in Dubuque County. All three are likely released captives. Rumors persist that a population exists in an oxbow of the Des Moines River in Ottumwa, but it was not possible to sample this in 1992.

Emydoidea blandingi. Blanding's turtles are primarily marsh turtles, but are occasionally found in rivers and adjacent marshes in the eastern two-thirds of Iowa (Figure 9). Several populations occur west of Des Moines, but the species is absent in southwestern and extreme western Iowa along the Missouri River. In eastern Iowa populations have been found associated with the Mississippi, Iowa, Cedar, and Wapsipinicon rivers. To date, no specimens have been collected along the lower Skunk or Des Moines rivers.

Sternotherus odoratus. Only five small populations of stinkpots have been located in Iowa (Figure 10). Many of these were discovered by recent surveys of Sutton and Christiansen (Dr. J. L. Christiansen, Pers. Comm.). They are confined to backwaters of the lower Cedar and Iowa rivers, and in sloughs of the Mississippi north into Clayton County (K. K. Sutton, Pers. Comm.). Records from Missouri (Johnson, 1987) indicate that *S. odoratus* has been found in the Missouri river as far north as Kansas City. In light

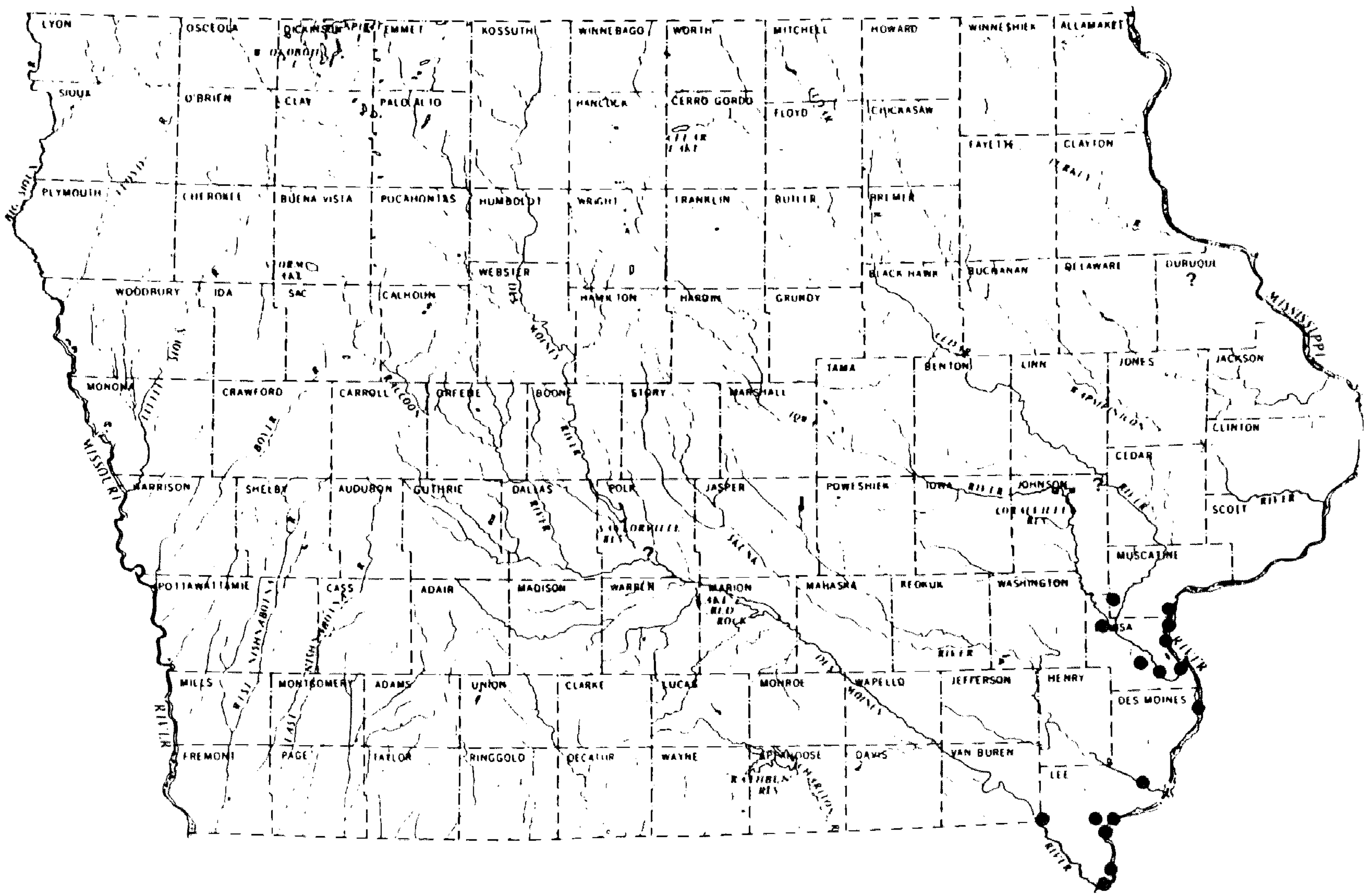

Figure 8. Collection locations for the red-eared turtle (*Trachemys scripta*).

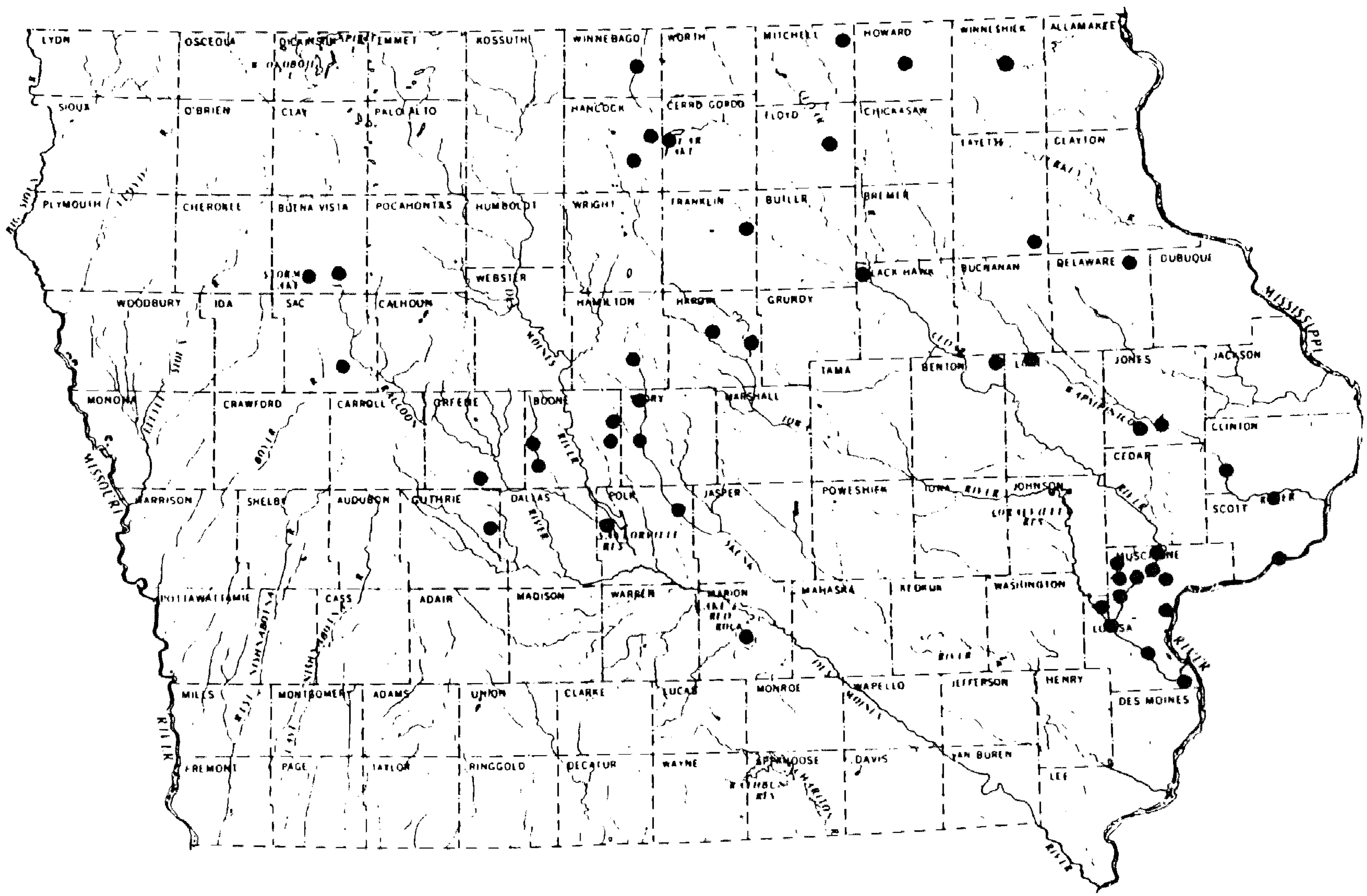

Figure 9. Collection locations for the Blanding's turtle (*Emydoidea blandingi*).

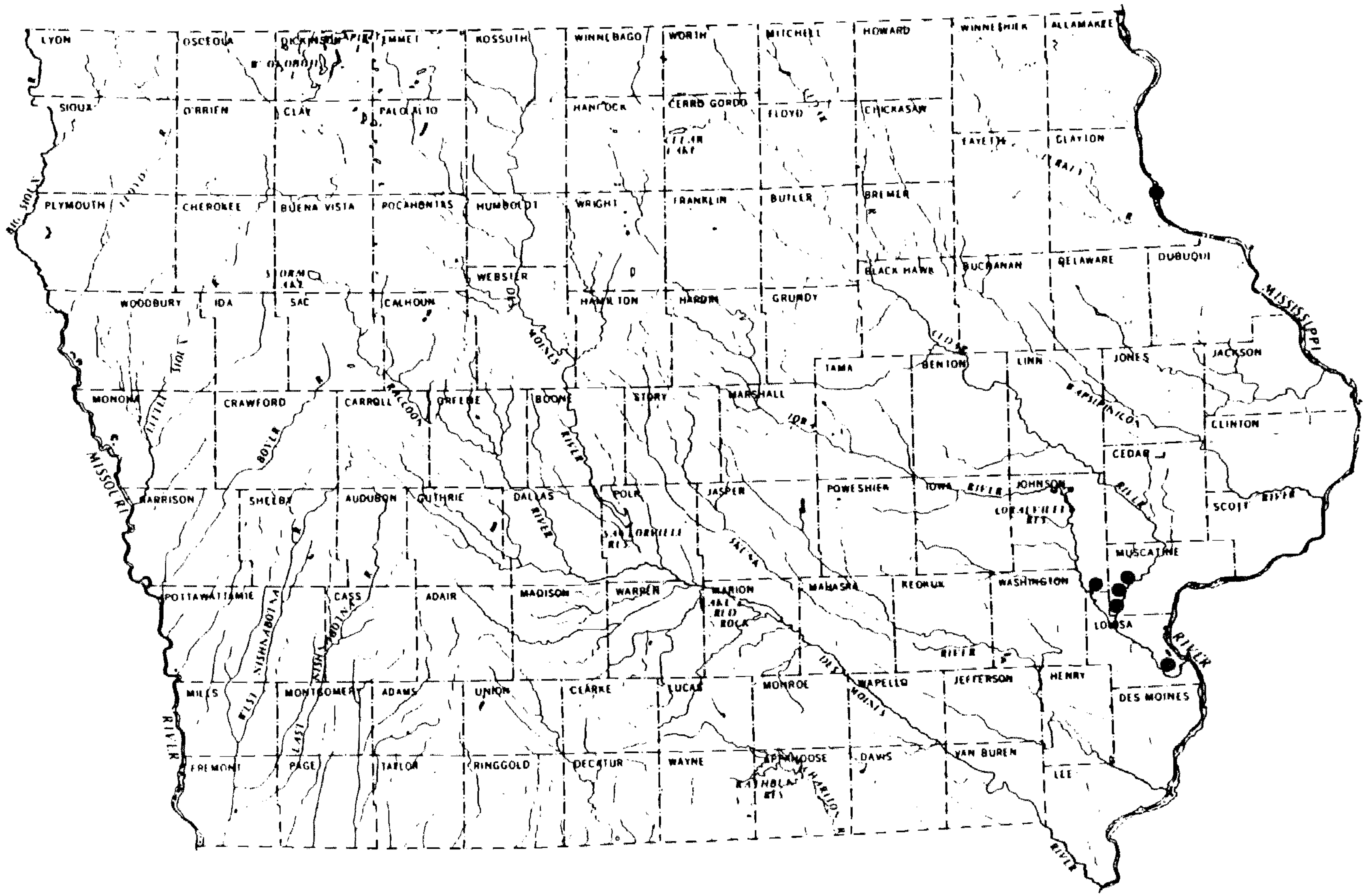

Figure 10. Collection locations for the stinkpot (*Sternotherus odoratus*).

of this, it is possible that specimens may eventually be found along the Missouri River in southwest Iowa.

Kinosternon flavescens spooneri. Illinois mud turtles are found where shallow bodies of water are adjacent to soils that are nearly pure sand (Christiansen and Bailey, 1988). These sites are limited to eastern Iowa, and are generally associated with the Mississippi River (Figure 11). Small *K. flavescens spooneri* populations have also been found along the Cedar and Iowa rivers. No specimens have been collected in areas along the lower Des Moines River.

Macroclemmys temmincki. No specimens of alligator snapping turtles in research collections or scientific literature exist from Iowa. Three unconfirmed specimens have been taken by fisherman; one crossing a road near the Iowa River, one from the Skunk River, and one from the Mississippi River near Keokuk (Figure 12). Smith (1961) reports that in Illinois *M. temmincki* is occasionally taken in the large downstream portions of inland rivers. It is likely that *M. temmincki* occasionally inhabits the Mississippi River on the east edge of Iowa, and possibly downstream portions of such Iowa rivers as the Skunk, Iowa, and Des Moines, but more sampling is needed to establish that this species supports a breeding population in Iowa.

Comparison of major river systems

Species richness was determined for the Missouri and Mississippi River drainages as well as for many of the largest individual rivers within each system (Tables 2 and 3). A distinct difference in the chelonian species composition of the two drainage systems is evident. Eleven species of turtles are found within the Mississippi River drainage, while the Missouri River drainage has five species present.

When the eastern rivers are compared (Table 2), the absence of several species from the Des Moines River becomes evident. Only five of eleven expected species were found in the state's largest inland river (Table 4). Species missing include: *G. geographica*

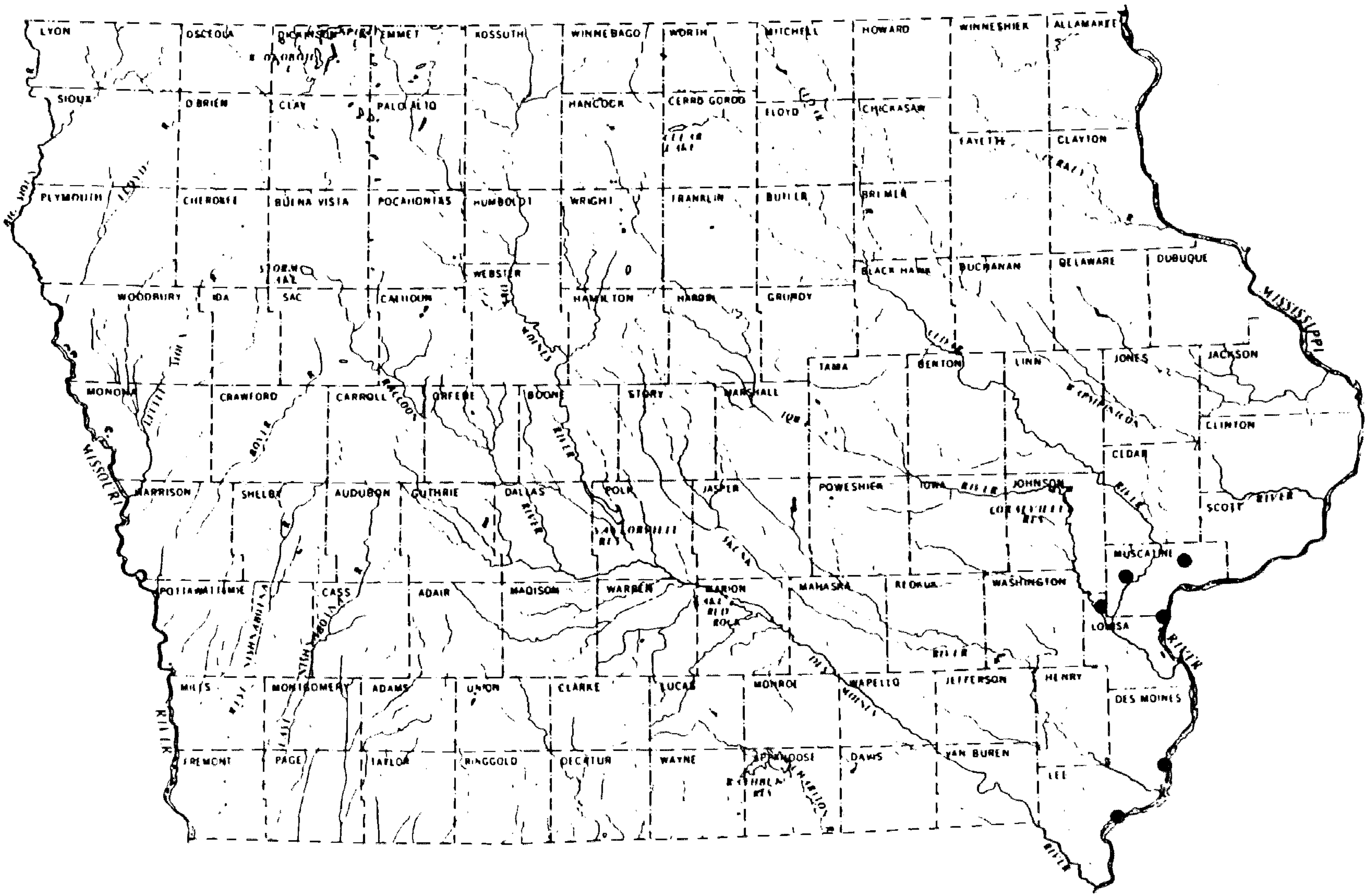

Figure 11. Collection locations for the Illinois mud turtle (*Kinosternon flavescens spooneri*).

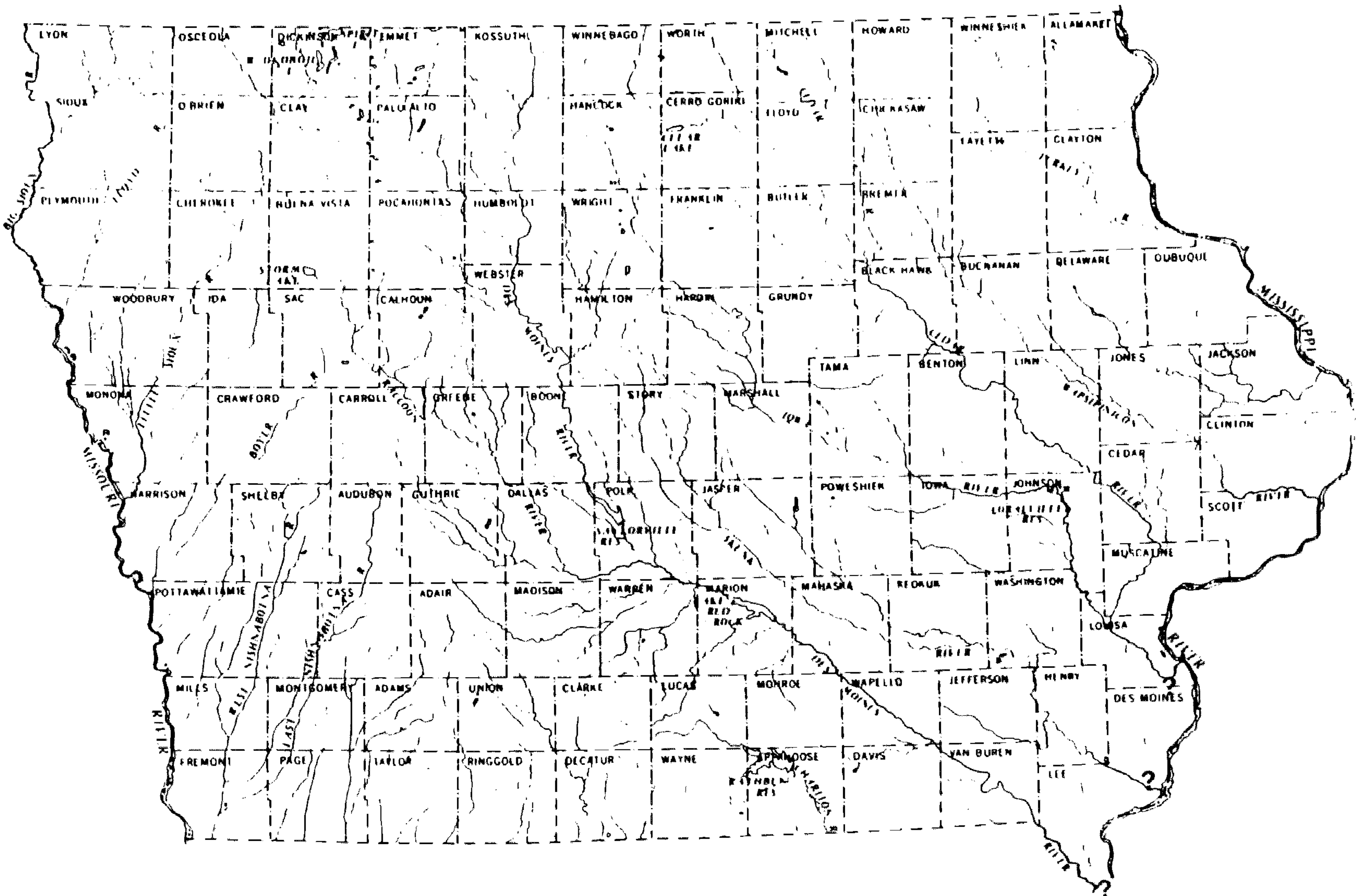

Figure 12. Locations of unconfirmed specimens of alligator snapping turtles (*Macroclemmys temmincki*).

Table 2. Chelonian species present in major eastern Iowa rivers and Red Rock Reservoir.

	Mississippi	Cedar	Iowa	Des Moines	Red Rock Res.
C. picta	X	X	X	X	X
C. serpentina	X	X	X	X	X
T. spiniferus	X	X	X	X	X
T. muticus	X	X	X	X	
G. pseudogeographica	X	X	X		
G. geographica	X	X	X		
T. scripta	X	X	X	X	
E. blandingi	X	X	X		
S. odoratus	X	X	X		
K. flavescens	X	X	X		
M. temmincki	X				

Table 3. Chelonian species present in major western Iowa rivers.

	Missouri	Little Sioux	Nishnabotna
C. picta	X	X	X
C. serpentina	X	X	X
T. spiniferus	X	X	X
T. muticus	X		
G. pseudogeographica	X		
E. blandingi			

Table 4. Species richness of major eastern Iowa rivers and Red Rock Reservoir.

	# Species Present	Total # Species Possible
Mississippi	11	11
Cedar	10	11
Iowa	10	11
Des Moines	5	11
Red Rock Res.	3	9

(Figure 7), *G. pseudogeographica* (Figure 6), *E. blandingi* (Figure 9), *S. odoratus* (Figure 10), and *K. flavescens spooneri* (Figure 11). In contrast, the three other eastern rivers (Mississippi, Cedar, and Iowa) all have high species richness, with the Mississippi river being the most diverse (Tables 2 and 4).

The western rivers also show some differences. As in the east, the largest western river, the Missouri, is the most diverse, with five of six expected species present (Table 5). The two inland streams show lower turtle diversity. Both the Little Sioux and Nishnabotna rivers appear to lack two key species, *T. muticus* and *G. pseudogeographica* (Table 3). Also notable is the absence of *E. blandingi* in the northern portion of the Missouri River, and apparently in the Little Sioux River.

Chelonian community similarities between the Mississippi River and it's Iowa tributaries, and the Missouri River and it's Iowa tributaries, were calculated using the Sørensen Coefficient (Brower and Zar, 1984). The coefficient is calculated by the formula

$$CC_S = \frac{2c}{s_1 + s_1}$$

where

CC_S = the coefficient of community

c = the # of species common to both communities

s_1 = the # of species in community 1

s_1 = the # of species in community 2.

The results of these calculations, based solely on the presence or absence of species, are summarized in Table 6 for the eastern rivers, and Table 7 for the western. The turtle composition of the Des Moines River is the least similar to the Mississippi (62%). In comparison, the turtle composition of the Cedar and Iowa rivers are very similar to the Mississippi (95%). When the Des Moines River and Red Rock Reservoir were compared

Table 5. Species richness of major western Iowa rivers.

	# Species Present	Total # Species Possible
Missouri	5	6
Little Sioux	3	6
Nishnabotna	3	5

Table 6. Chelonian community similarity between the Mississippi River and other major eastern Iowa rivers and Red Rock Reservoir. 1 = all species in common ; 0 = no species in common.

	Sørensen Coefficient
Mississippi	1.0
Cedar	.95
Iowa	.95
Des Moines	.62
Red Rock Res.	.43

Table 7. Chelonian community similarity between the Missouri River and other major western Iowa rivers. 1 = all species in common ; 0 = no species in common.

	Sørensen Coefficient
Missouri	1.0
Little Sioux	.75
Nishnabotna	.75

using the same formula, it was found that the two communities were 75% similar. The lower similarity is due to the absence of *T. muticus* in the reservoir (Table 2). In the west, both the Little Sioux and Nishnabotna rivers lacked two species found in the Missouri and were 75% similar to that river (Table 7).

The number of specimens that have been collected, during this and previous studies, from all the studied rivers, and Red Rock Reservoir, are shown in Tables 8 and 9. The information in these tables was used to calculate diversity indices for each river using the Shannon Diversity Index (Brower and Zar, 1984) as follows:

$H' = (N \log N - \sum n_i \log n_i)/N$

where

H' = the diversity index

N = total # of individuals of all species

n_i = # of individuals in the ith species.

These calculations show the Des Moines River to have lower turtle diversity than the other eastern rivers ($H' = .62$), while the Mississippi River is the most diverse ($H' = .88$) (Table 10). In the Missouri River drainage, the two inland rivers have lower turtle diversity ($H' = .46$ and $H' = .35$) than the Missouri River ($H' = .58$) (Table 11). These results must be used with caution due to the following two sources of error: 1) certain rivers have been sampled more thoroughly than others; and, 2) certain species have been kept as specimens more frequently than others. In general however, the differences in diversity are consistent with the differences in community similarity. The Des Moines River is the least diverse of the eastern rivers; and, the inland rivers of western Iowa have a lower turtle diversity than the Missouri River.

Red Rock Reservoir

During the survey of the lake, a surprisingly small number of trappable locations were found. Many of the bays that looked promising on maps possessed characteristics

Table 8. Number of specimens of each species collected from major eastern Iowa rivers and Red Rock Reservoir.

	Mississippi	Cedar	Iowa	Des Moines	Red Rock Res.
C. picta	67	58	53	33	4
C. serpentina	13	26	21	21	2
T. spiniferus	57	31	5	18	3
T. muticus	41	13	1	11	
G. pseudogeographica	40	6	3		
G. geographica	30	1	2		
T. scripta	10	1	4	4	
E. blandingi	2	13	9		
S. odoratus	1	9	1		
K. flavescens	12	1	2		
M. temmincki	1				

Table 9. Number of specimens of each species collected from major western Iowa rivers.

	Missouri	Little Sioux	Nishnabotna
C. picta	11	4	14
C. serpentina	9	2	4
T. spiniferus	1	3	2
T. muticus	2		
G. pseudogeographica	13		
E. blandingi			

Table 10. Chelonian diversity indices for major eastern Iowa rivers and Red Rock Reservoir. 1 = high diversity ; 0 = low diversity.

	Shannon Diversity Index
Mississippi	.88
Cedar	.77
Iowa	.66
Des Moines	.62
Red Rock Res.	.46

Table 11. Chelonian diversity indices for major western Iowa rivers. 1 = high diversity ; 0 = low diversity.

	Shannon Diversity Index
Missouri	.58
Little Sioux	.46
Nishnabotna	.35

which made them unsuitable habitat. For example, they lacked basking sites, the water was too deep immediately off shore, the banks were slab-sided, and/or human use was excessive. It was discovered, while scouting for trapping locations, that most floating basking material (i.e. logs) had been deposited as much as from 20 - 50 feet away from the water during flood events, the most recent in the summer of 1991. In addition, raising the permanent pool level of Red Rock by eight feet in April of 1992 caused the submergence of any permanent basking material that had formerly been available. The effect of these two conditions was to leave bays with large expanses of open water and virtually no basking logs. Consequently, turtles were seen basking only two times during the study. Trapping success was hindered by the large fluctuation in the water level. After heavy rain the water level of a bay sometimes rose up to two feet overnight, and all traps were found totally submerged the following morning. The fast rising water increased the amount of suspended silt as well. In addition to rising very quickly, the water level often dropped just as suddenly, and traps that were submerged the night before would be left mostly out of the water the next morning.

All suitable trapping locations within Red Rock Reservoir were sampled and the results are shown in Table 12. The species collected at each location are shown in Figure 13. A total of 70 turtles, representing three species, were caught during 269 trap nights (one trap per night = one trap night) at Red Rock. Chelonian species richness in Red Rock Reservoir was lower than expected, with only three of nine possible species found in the reservoir (Table 4). Snapping turtles were most commonly caught, and spiny soft-shells were captured at several locations and in large numbers at one (Table 12). Most significant was the apparent lack of smooth soft-shells in the lake. Conversations with long-time local residents, local bait dealers, Army Corps of Engineer personnel, and Dick McWilliams, Fisheries Biologist with the Iowa Department of Natural Resources, revealed no local knowledge of turtles other than painted, snapping, and soft-shells in the reservoir.

Table 12. Trapping locations and species caught at each location in Red Rock Reservoir.

Location	Description	*C. picta*	*C. serpentina*	*T. spiniferus*
1	South River Wildlife Refuge	1	7	
2	Swan Wildlife Refuge		1	4
3	Ballard Creek Bay		5	15
4	South Boat Ramp West of Hwy 14	11	6	
5	Bay just W. of Hwy 14 North Side of Reservoir	3	4	
6	Teter Creek Bay		1	
7	North Boat Ramp East of Hwy 14			1
8	Whitebreast Creek Bay 1	4	2	2
9	Whitebreast Creek Bay 2	1	2	
	Totals	20	28	22

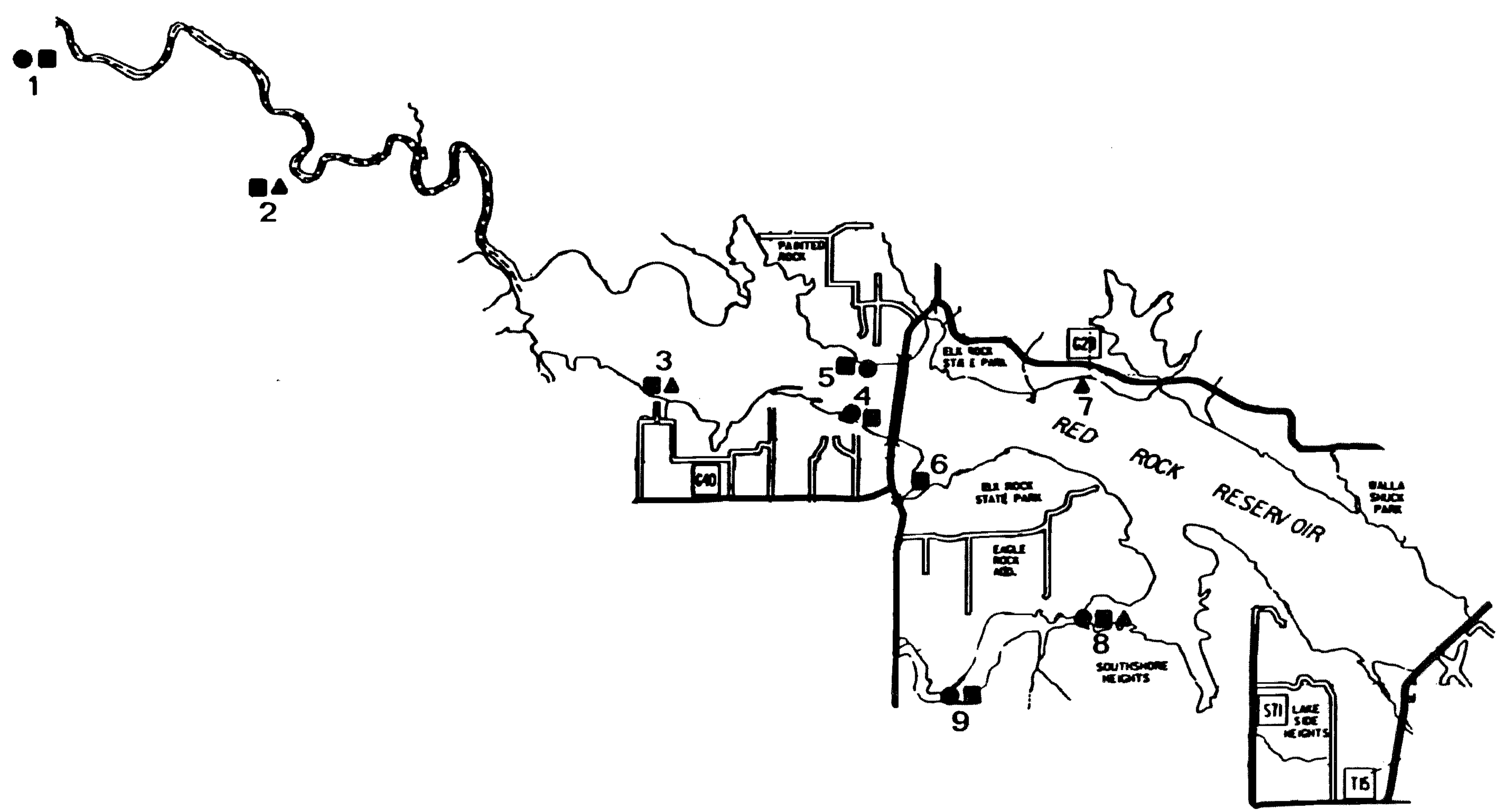

Figure 13. Collection locations for *Chrysemys picta*, *Chelydra serpentina*, and *Trionyx spiniferus*; dots, *C. picta*; squares, *C. serpentina*; triangles, *T. spiniferus*.

During the course of the study, it appeared that certain species were not being found together as often as might be expected. To determine the statistical significance of these observations, species association for Red Rock Reservoir was calculated by constructing a 2x2 table and using the following adjusted formula (Pielou, 1974):

$$X_C^2 = \frac{(|\,ad - bc\,| - N/2)^2\,N}{(a+b)(c+d)(a+c)(b+d)}$$

where

X_C^2 = the association index

a = # of samples containing both species 1 and 2

b = # of samples containing only species 2

c = # of samples containing only species 1

d = # of samples containing neither species.

The value obtained was then compared with the critical value (3.84) for a 95% significance test. Values larger than 3.84 indicate a highly significant result. Positive or negative association was determined by the relationship of *ad* to *bc*. If $ad > bc$, then association is positive. If $ad < bc$, then association is negative.

The results of these calculations are shown in Table 13. *Chrysemys picta* and *C. serpentina* appear to be positively associated, with an index value of .01. This value is considerably lower than the critical value (3.84) suggesting that this result could happen merely by chance. Conversely, associations between *C. picta* and *T. spiniferus*, and *C. serpentina* and *T. spiniferus* were found to be negative. Index values for these associations were 5.4 and 5.1 respectively. The probability of obtaining values this large if the species were independent is less than 5%. It is therefore concluded that the species are independent (not particularly associated). The presence of one makes that of the other less likely.

Table 13. Associations between turtle species in Red Rock Reservoir.

	X_c^2	Association
C. picta x C. serpentina	.01	Positive
C. picta x T. spiniferus	5.4*	Negative
C. serpentina x T. spiniferus	5.1*	Negative

* Significant at P < .05

DISCUSSION

Stream modification

Turtle diversity in Iowa's rivers decreases from east to west across the state. The difference in diversity between eastern and western rivers can be explained in some measure by natural factors. The composition of any one community is determined in part by the species that happen to be distributed in the area and can grow and survive under the prevailing conditions (Smith, 1980). Therefore, the observed differences between the turtle communities of the Mississippi River drainage and the Missouri River drainage may be due in large part to climatic and topographical differences. However, when rivers within the same drainage system are compared, climatic and topographical factors play a smaller role.

Human activities often result in a reduction or loss of diversity within ecosystems, particularly through the loss of rare species (Patrick, 1988). The present study suggests that stream modification has lowered the diversity of riverine turtles in some Iowa streams by eliminating intolerant forms. Simpson et al. (1982) report the decline of certain fish populations due to early channelization, and that these populations have been replaced with forms that are more tolerant or better adapted to the new habitat. Paragamian (1987) also found unusually low numbers of intolerant fish species in channelized waterways.

The mechanism for this elimination appears to be a reduction in habitat diversity, creating a more homogeneous and simplified environment. Channelized streams lack many of the characteristics that provide habitat diversity (Brookes, 1988; Bulkley et al., 1976; Paragamian, 1987; Simpson et al., 1982; Smith and Shields, 1990). Under such circumstances, the particular set of environmental conditions required for intolerant species to survive are removed, resulting in a loss of those species. At the same time more opportunistic species are able to move into the disturbed areas and exploit the new conditions found there. Consequently, species diversity in the community is lowered, while the abundance of individuals in the community remains nearly the same, giving the appearance of a healthy community. But, as Vandre (1975) points out, the total number of species and the number of riparian indicator species are more reliable indicators of habitat quality than the total number of individuals at that time.

The lower Des Moines River, in eastern Iowa, provides a good illustration of the impact of stream modification on riverine turtles. In the present study, it was found that the Des Moines River was the least diverse, with respect to turtles, of the major rivers in the Mississippi River drainage in Iowa (Tables 4 and 10). The lower Des Moines River, from Red Rock Reservoir south to its confluence with the Mississippi, contains only four of eleven possible species. Species missing include *G. pseudogeographica*, *G. geographica*, *T. muticus*, *E. blandingi*, *S. odoratus*, and *K. flavescens spooneri* (the eleven *T. muticus* shown in Table 8 for the Des Moines River were all caught within the city limits of Des Moines and points farther north). All of these species have specific and unique habitat requirements that are often no longer present after channelization.

The data in this study suggest that *G. pseudogeographica*, *T. muticus*, and *E. blandingi* are particularly affected by stream modification. Not only are they missing from the lower Des Moines River, but are also absent from the Little Sioux and Nishnabotna rivers in western Iowa, both of which have undergone extensive channelization (Bulkley et al., 1976; Harlan et al., 1987; Welker, 1967). Conant and Collins (1991) report that populations of several species of *Graptemys* have been severely decimated by the channelization of many southern rivers. Johnson (1987) also suggests that *Trionyx* and *Graptemys* populations are declining in Missouri due to siltation and channelization.

Graptemys pseudogeographica is a shy species that inhabits slow moving rivers, river sloughs, and oxbow lakes (Carr, 1952; Johnson, 1987). In the Missouri River, Timken (1968) found the highest densities of *G. pseudogeographica* in backwater habitats, and the lowest densities in floodplains of large reservoirs. In Iowa, Christiansen and Bailey (1988) report the species is limited to the quiet inlets of rivers and nearby ponds and lakes. While the lower Des Moines may have been a large, slow moving river in the past, especially in southeast Iowa, today the channel is very fast and a large percentage of the river banks are leveed and riprapped. In addition, very few quiet inlets, sloughs, and oxbows remain. False map turtles are also confirmed baskers, requiring an abundance of basking sites (Carr, 1952; Johnson, 1987; Smith, 1961). Many potential basking logs are available in the river, but these are often located near the main channel, which may make them undesirable as *G. pseudogeographica* normally avoids strong current (Carr, 1952). A related species, *G. geographica*, is also absent from the Des Moines River. This river species often inhabits oxbows and sloughs. As with *G. pseudogeographica*, map turtles require an abundance of basking sites (Johnson, 1987). Both species feed heavily on mollusks (Carr, 1952; Smith, 1961) which are frequently reduced or eliminated in rivers with heavy siltation or that have been channelized (Simpson et al., 1982).

If *T. muticus* has not been eliminated from the lower Des Moines River, then its numbers are certainly reduced. To date, no specimen has been taken from the river south of the city of Des Moines. This is particularly interesting since they are regularly taken by fisherman within the city limits of Des Moines. The related species, *T. spiniferus*, is commonly caught in the lower Des Moines River. Williams and Christiansen (1981) found that *T. muticus* are more specialized in their habitat requirements than *T. spiniferus*. Smooth soft-shells bask almost entirely on sandy or muddy beaches, or in shallow water associated with such beaches (Williams and Christiansen, 1981). In addition, they prefer to nest on clean, level sandbars or sandy shores that are free from weeds, trash, and sediments (Goldsmith, 1944). Level, clean sandbars or gently sloping sand banks are not common along the river. Those that are present are often found in the middle of the channel.

Two conditions present in the lower Des Moines may have contributed to the decline of *T. muticus*. Flooding was always present, but due to such practices as diking and dredging, the floodwaters are now confined to the main channel of the river. This results in a scouring effect which removes the loose sand that had formerly been deposited as sandy shores and redistributes it in other areas. The consequence is a reduction in the number of suitable nest sites. Those that are present are often covered with water during critical nesting periods. Goldsmith (1944) reports that when water is high, covering sandy areas, the normal egg laying habits of *T. muticus* are disturbed. In addition, many banks have been riprapped covering unstable substrates, such as sand, with large rocks. These large rocks, in all likelihood, interfere with the mobility of the turtles. Along with floodwaters commonly come heavy silt loads. The Des Moines has historically had problems with siltation (U. S. Army Engineers, 1975). As water levels drop, silt is deposited on top of sandbars, making them unappealing to smooth soft-shells. Moll (1980) reports that smooth soft-shell turtles have declined in the Illinois River due to silt covering the sandbars needed for nesting. Siltation may also affect the hunting success of *T. muticus*. The turtle is best adapted to catching prey in the water column (Williams and Christiansen, 1981). Heavy silt loads may hinder their ability to locate prey. The combination of floods and heavy silt loads not only affects turtles, but appears to be an important limiting factor to fish in the Des Moines River as well (Starrett, 1951).

Channelization to facilitate drainage for agriculture may have far reaching effects which extend into the floodplain (Brookes, 1988). Loss of wetlands, pools, meanders, and sheetwater are consequences of channelization that could potentially affect turtles such as *E. blandingi*. In Iowa, Blanding's turtles are restricted to the vicinity of marshes, sloughs, or quiet river bays where water is less than four feet deep and emergent vegetation is dense (Christiansen and Bailey, 1988). Nearly all of this type of habitat along the lower Des Moines River has been drained to provide more land for agriculture. In many areas farm ponds have replaced natural marshes. Christiansen and Bailey (1988) report that *E. blandingi* tend not to remain in artificial farm ponds. They are more terrestrial than most aquatic turtles and may move overland seeking new areas when marshes are drained.

It should be mentioned that stream modification alone may not be totally responsible for the absence of certain species in the Des Moines River. As stated earlier, natural factors also play a role in determining community composition. The middle segment of the lower Des Moines can best be described as a gorge with steep rock banks (Harlan et al., 1987). The channel in this area is deep and fast. These conditions alone may make the area unsuitable turtle habitat. The combination of natural elements and channelization may work together to exclude turtles.

Three species, *C. picta*, *C. serpentina*, and *T. spiniferus*, are common and relatively abundant in the Des Moines, Nishnabotna, and Little Sioux rivers. Each is a fairly tolerant species able to adapt to a wide range of habitat conditions. Of all turtle species in Iowa, these seem to be the least affected by stream modification.

Reservoirs

In the United States, excluding the Great Lakes, the area covered by reservoirs exceeds the area covered by natural lakes (Marzolf, 1984). Reservoirs would seem to be an ideal habitat for a variety of turtles. The data in this study suggest otherwise. Red Rock Reservoir was found to have a lower diversity than the Des Moines River, with only three out of a possible nine species present in sufficient numbers to be captured in this study (Table 4). Other workers have also found diversity to be lower in reservoirs than in their associated rivers (Chellappa, 1990; Neck, 1989).

A possible explanation for the low diversity is the unstable environment of the reservoir, resulting from substantial water level fluctuations. The U. S. Army Corps of

Engineers (1991) report that natural resources within Red Rock are impacted by extreme lake level fluctuations. Platt (1973) compared the vertebrate communities of Coralville Reservoir with those of Cone Marsh and found a massive trophic simplification and a reduction in the number of vertebrate species present in the reservoir. He concluded that this had occurred due to the highly fluctuating water levels of the reservoir. Unstable environmental conditions favor tolerant species that are able to adapt to an environment that is constantly in flux.

Periodic and seasonal flooding result in an area around the margin of the lake, known as a "Bath Tub Ring", that is devoid of vegetation and experiences increased erosion (U. S. Army Engineers, 1975). This area at Red Rock is anywhere from 5 - 40 feet wide and in many places composed of loose rock. Sand banks are found in only a few of the bays. The "Bath Tub Ring" may hinder turtles as they search for sites to lay their eggs. On two occasions during this study the eggs of *C. serpentina* were found within the "Bath Tub Ring" area. One set of eggs was deposited on top of the ground, a few feet apart, in a line extending from the waters edge up a steep rock bank. It appeared as though the female was attempting to reach a wooded area approximately 30 feet up the bank. The second set of eggs was deposited in a shallow nest that had been constructed in loose rock approximately 10 feet from the water. The nest had been dug up by a raccoon (*Procyon lotor*) and the eggs had been eaten. Both examples illustrate the difficulty encountered by turtles while trying to locate suitable nest sites. They also suggest that the area would favor species that are able to adapt to a wide range of nesting conditions. Nests with eggs in this zone are also in danger of being inundated with water, resulting in the death of the embryos.

Basking sites are also severely limited due to frequent flooding. Nearly all floating basking material has been relocated anywhere from 10 - 40 feet up the bank in most areas. This could potentially prevent such species as *G. pseudogeographica* and *G. geographica,* which require abundant basking sites, from becoming established in the reservoir. Frequent flooding also results in heavy silt loads being deposited in the reservoir. Marzolf (1984) states that reservoirs are sediment traps and currents are sufficient to maintain particulate matter in suspension. Recent estimates by the U. S. Army Corps of Engineers (1991) put the average sediment yield for Red Rock at 3,500 ac-ft per year. Siltation may affect turtles by reducing visibility for those species that hunt by sight, and by reducing the density of certain prey species.

The most notable species missing from Red Rock is *T. muticus*. Several conditions present in the reservoir may act to exclude smooth soft-shells. An important factor may be the lack of suitable nest sites. Smooth soft-shells prefer to nest on clean sandy beaches close to the water (Goldsmith, 1944). The few sandy areas present at Red Rock are often overgrown with vegetation. *Trionyx muticus* seldom nest in sandy inlets with growths of weeds, trees, and shrubs (Goldsmith, 1944). The related species, *T. spiniferus*, which is common in Red Rock, will nest farther away from the water, and in vegetation (Carr, 1952). Spiny soft-shells were only caught in bays that had a stream entering them. It is assumed that these habitats provide abundant food supplies for this predominantly benthic feeder, and suitable nest sites near the mouth of the stream, where the soil is sandy with moderate to heavy vegetation.

Availability of prey is another possible explanation for the absence of *T. muticus* in the reservoir. Smooth soft-shells are active predators that often feed in the water column (Williams and Christiansen, 1981). In Iowa, their diet consists of approximately 70% insects and 20% small fish that are eaten alive (Williams and Christiansen, 1981). Platt (1973) reports that water fluctuations eliminate insect food supplies and reduce or eliminate certain fish species by lowering their reproductive success. In addition, Platt found a corresponding decline in insectivorous and piscivorous fish species in Coralville Reservoir.

It seems logical that a turtle species, whose main diet consists of insects and small fish, would suffer the same fate.

Some species in a community may occur together (or apart) more frequently than by chance. Positive associations may result from food-chain coactions or similarities in response to environmental conditions, while negative associations may result from interspecific competition or adaptations to different sets of environmental conditions (Smith, 1980). The associations of the turtle species in Red Rock Reservoir (Table 13) are probably due to the habitat requirements of the three species. Based on their preferred habitats, it would be predicted that *C. picta* and *C. serpentina* would be found in lentic habitats, while *T. spiniferus* would favor lotic habitats. This difference was observed during the study. In the reservoir spiny soft-shells were only caught in bays that had streams running into them which created a current, painted and snapping turtles were caught more frequently in bays without a stream than in bays with streams.

Conclusions

This study suggests that stream modification lowers the diversity of riverine turtles by eliminating intolerant species. The mechanism for this elimination seems to be a reduction in habitat diversity after modification, resulting in a more homogeneous and simplified environment. In addition, the highly fluctuating water levels of the reservoir create unstable conditions that favor more tolerant species. In Iowa, Blandings (*Emydoidea blandingi*), false map (*Graptemys pseudogeographica*), and smooth soft-shell turtles (*Trionyx muticus*) appear to be most affected by stream modification. While painted (*Chrysemys picta*), snapping (*Chelydra serpentina*), and spiny soft-shell turtles (*Trionyx spiniferus*) are least affected.

The results of this study should be viewed as a starting point in answering the question of how stream modification affects riverine turtles. More work remains to be done before a complete picture can be seen. Two possible future projects that would better define the problem are presented here. First, a comparison of the turtle species in Coralville Reservoir with those in the Iowa River would be useful. The Iowa River has a very diverse turtle fauna (10 out of 11 possible species), several of which are found both above and below the reservoir. If predictions based on this study are correct, the difference in turtle diversity between the Iowa River and Coralville Reservoir should be dramatic. Second, a comprehensive survey of the Skunk River, from Ames south to its confluence with the Mississippi River, would be helpful in answering questions regarding channelization. Comparisons between the Skunk and other eastern rivers could be made to determine if differences in diversity exist. In addition, location of channelization projects on the Skunk River are well known. Comparisons between channelized and unchannelized reaches could be made to determine if any differences exist. The results of a replicated field study such as this would yield strong inferences, and be widely applicable.

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